INERTIAL RESISTANCE EXERCISE APPARATUS AND METHOD

Background

It is a well known form of exercise to create a resistance to muscular contraction or elongation. Exercise producing resistance may be provided by free weights, i.e., barbells or plates attached to a bar, or machines utilizing, for example, weight stacks, compressed air, hydraulics, magnets, friction, springs, bending flexible rods, rotating fan blades, mechanical dampers or the users own body weight. A conventional exercise with free weights, for example, involves a "positive" movement in which the muscle under training is contracting to lift a weight and a "negative" movement in which that muscle is elongating to lower the weight. Many exercise machines emulate the exercise movements used in free weight training.

There are many disadvantages to exercising with both free weights and these conventional exercise machines. For instance, free weights are potentially hazardous without a partner to "spot" the user, and it is difficult and time consuming to adjust the amount of weight to be used in order to perform a different exercise or to accommodate another person of differing strength. Various exercise machines tend to be heavy and/or bulky and do not offer the intensity, range-of-movement and variety of movement of free weights. Also, both free weights and weight machines cannot be used in a gravity-free environment, such as encountered by astronauts.

An alternative form of exercise utilizes inertia to provide exercise-producing resistance. Such exercise is based on the principle that force is required to rotationally accelerate a mass, i.e., to increase or decrease the rotational velocity of a mass. An inertial exercise device has several advantages over both free weights and conventional exercise machines. Less bulk is required because the difficulty of the exercise depends not only on mass but also on the angular acceleration of mass. No partner is required as with free weights. Further, an inertial exercise device does not require gravity.

Existing exercise devices utilizing inertia, however, suffer from several disadvantages. Many such devices provide only a positive work exercise. Further, it is often difficult to vary the resistance of inertial exercises. Finally, unlike free

weights or some exercise machines, existing inertia-based exercise devices have difficulty providing a constant resistance and/or constant speed of movement.

Summary

The present invention relates to an exercise apparatus and method in which exercise-producing resistance is provided by the inertia of a rotatable mass. One aspect of this invention employs a flywheel which is axially mounted to a rotatable axle. One end of a line is attached to the axle. In an initial position, a portion of the line is wrapped about a portion of the axle. A user applying a force to the unattached end of the line creates an accelerating torque on the axle, causing the axle to begin rotating and the line to begin unwrapping. As the user increases the force on the line, the axle and flywheel rotate with increasing velocity. When the line is completely unwrapped from the axle, inertia causes the axle to continue rotating in the same direction. This continued rotation of the axle causes the line to wrap about the axle in the opposite direction from the initial position of the line. The user then applies a force to the line to slow the rotation of the axle and decelerate the flywheel. The user applied force preferably stops the rotation of the flywheel and axle when a portion of the line is wrapped about a portion of the axle. In one embodiment, the line may wrap and unwrap around an axle with a gradually increasing diameter. Preferably, this causes the acceleration of the axle to be continuously changing.

Another aspect of this invention is an exercise apparatus with two axles which are interconnected with a synchronizing assembly such that both axles rotate. One end of a line is attached to the first axle. In an initial position, a portion of the line is wrapped about a portion of the first axle. A flywheel is axially mounted to the second axle. A user applying a force to the unattached end of the line creates an accelerating torque on the axle, causing the axle to begin rotating and the line to begin unwrapping. Due to the synchronizing assembly, the second axle also rotates, which causes the flywheel to rotate. When the line becomes completely unwrapped from the first axle, the inertia of the flywheel causes the second axle to continue rotating in the same direction and, hence, the first axle also continues to rotate in the same direction. Rotation of the first axle causes the line to wrap about the first axle in the opposite direction from the initial position of the line. The user then applies force to the line

to slow the rotation of the first axle and, due to the synchronizing assembly, also the second axle, causing the rotational velocity of the flywheel to decrease. The user applied force preferably stops the rotation of the flywheel and axles when a portion of the line is wrapped about a portion of the first axle. In one embodiment, the line wraps and unwraps around an axle with a generally increasing diameter. In another embodiment, a generally constant force applied to the line results in a generally continuously changing acceleration of the axle.

Yet another aspect of this invention provides a rotatably mounted axle and a flywheel mounted to the axle. A linkage connects a grip to the axle. A force applied to the grip in a first direction causes the axle and flywheel to rotate in one direction. A force applied to the grip in a second direction causes the axle and flywheel to slow or stop rotating in that direction. A continued force in the second direction may cause the axle and flywheel to rotate in the opposite direction.

The present invention also relates to a method of creating resistance for exercising which utilizes the rotational inertia of a flywheel. The user exercises his or her muscles by exerting a force which alternately accelerates and decelerates a rotating flywheel. In one aspect of the invention, the user applies a positive work movement to the apparatus to increase the rotational velocity of the flywheel and a negative work movement to the apparatus to decrease the rotational velocity of the flywheel. The positive work movement creates a force which is translated into a torque. That torque is applied to the flywheel in a first direction to accelerate the flywheel. A negative work movement creates a second force which is translated into a second torque. The second torque is applied to the flywheel in a direction opposite the first direction. This causes the flywheel to decelerate.

Brief Description of the Drawings

FIG. 1 is a perspective view of a preferred embodiment of an inertial resistance exercise device according to the present invention, illustrating a line attached at one end to a flywheel assembly axle and a spool mechanism;

FIGS. 2A-C are schematic representations of the flywheel assembly illustrated in **FIG. 1** depicting various line positions for the particular pivot location shown;

FIGS. 3A-C are schematic representations of the flywheel assembly illustrated in **FIG. 1** depicting various line positions for the particular pivot location shown;

FIGS. 4A-C are schematic representations of the flywheel assembly illustrated in **FIG. 1** depicting various line positions for the particular pivot location shown;

FIG. 4D is a schematic representation of the flywheel assembly illustrated in **FIG. 1** without the spool mechanism.

FIG. 5 is a perspective view of another preferred embodiment of the inertial resistance exercise device illustrating dual axles and a spool mechanism;

FIG. 6 is a perspective view of yet another preferred embodiment of the inertial resistance exercise device illustrating a variable-slope conical spool mechanism and a governor-like flywheel mechanism;

FIG. 7 is a perspective view of still another preferred embodiment of the inertial resistance exercise device illustrating a line with both ends attached to a flywheel assembly axle;

FIG. 8 is an illustration of the inertial resistance exercise device incorporating the flywheel assembly shown in **FIG. 1** and illustrating potential configurations and grips to accommodate a variety of exercises;

FIG. 9 is a perspective view of the inertial resistance exercise device incorporating the dual-axle flywheel assembly of **FIG. 5** without a spool and illustrating an arm exercise configuration;

FIG. 10 is a perspective view of an inertial resistance exercise device incorporating the flywheel assembly illustrated in **FIG. 7** and illustrating an arm exercise configuration.

FIG. 11 is a perspective view of the inertial resistance exercise device incorporating the dual-axle flywheel assembly shown in **FIG. 5** without a spool and illustrating a climbing exercise configuration; and

FIG. 12 is a perspective view of the inertial resistance exercise device incorporating the flywheel assembly illustrated in **FIG. 7** and illustrating a climbing exercise configuration.

Description of the Preferred Embodiments

FIG. 1 illustrates an embodiment of the inertial resistance exercise device according to the present invention. A mass **10**, preferably in the form of a flywheel, is mounted on an axle **20**. A spool **30** may also be mounted to the axle **20**. In an alternative embodiment, the flywheel **10** may be incorporated into the spool **30**. As discussed below, the spool **30** may be configured in a number of shapes and sizes depending upon the manner and intensity of exercise desired by the user. The axle **20** is preferably supported by bearings **22**. Proximate one end of the axle **20** is an anchor **24**. One end of a line **40** is attached to the axle **20** at the anchor **24**. The opposite end of the line **40** is attached to a grip **50** or other member which allows a user to apply force to the line **40**.

As an alternative to the embodiment illustrated in **FIG. 1**, the mass of the flywheel **10** can be incorporated into the spool **30**, eliminating the need of a separate flywheel and spool. As another alternative embodiment, the spool **30** can be eliminated, so only a flywheel **10** is mounted on the axle.

In a preferred embodiment, the line **40** is supported between its two ends by a pivot **60**. The pivot **60** preferably can be located at one of multiple adjustable pivot positions. For instance, the pivot **60** is preferably positioned at one of multiple locations located parallel to the axle **20**. Additionally, the pivot **60** is preferably positioned at one of multiple locations perpendicular to the axle **20**. One of ordinary skill in the art will appreciate that the pivot **60** may be located at a wide variety of locations and distances from the axle **20**. Additionally, the pivot **60** may be movable relative to the axle **20** during exercise or located at a single fixed pivot point. The multiple pivot points allow the difficulty of the exercise to be adjusted, as described below. The pivots **60** preferably comprise pulleys or other similar rotatable members.

The apparatus shown in **FIG. 1** allows a user to exercise utilizing a positive work portion followed by a negative work portion to complete one cycle or "repetition" of the exercise. To complete an exercise "set," a user would perform the desired number of such repetitions. The positive work portion of each repetition of the exercise begins with the line **40** in a wrapped position **44**. In this position, the line **40** is wrapped around a portion of the axle **20**, a portion of the spool **30**, or some combination thereof, depending on the position of the pivot **60**. In order to exercise,

the user applies a force to the grip **50** which, translated through the line **40**, creates an accelerating torque on the axle **20**. This torque causes the axle **20** to turn and the rotational velocity of the flywheel **10** to increase. As the user pulls the grip **50** in a direction away from the axle **20**, typically contracting a muscle or muscle group, the line **40** unwraps from the axle **20**. The axle **20** turns in either a clockwise or counterclockwise manner, depending on the direction that the line **40** unwraps from the axle **20**. Eventually the unwrapping line reaches its fully unwrapped position, illustrated by broken line **42**. The inertia of the flywheel **10** causes the axle **20** to continue rotating in the same direction, and the line **40** will begin to wrap around the axle **20** and/or a portion of the spool **30** in a direction opposite its initial direction. At this point, the negative work portion of the exercise begins.

The negative work portion of the exercise starts with the line **40** in its unwrapped position **42** and with the axle **20** rotating at an angular velocity. As the axle **20** rotates, the line **40** begins to wrap around the axle **20** in the opposite direction of that during the positive work portion of the exercise. As the line wraps around the axle **20** and/or a portion of the spool 30, the line **40** typically pulls the grip **50** towards the axle **20**. The user now must apply a resisting force to the grip **50**, typically with the user's muscles lengthening under this force. This force, translated through the line **40**, creates a decelerating torque on the axle **20**, reducing the angular velocity of the axle **20**. Eventually, the flywheel 10 ceases rotation, completing one cycle or repetition of the exercise. At the end of each repetition, it will be understood that the line **40** is wrapped around the axle **42** and spool **30** in the opposite direction from the previous repetition.

A user, for example, may exercise the biceps by grasping the handle **50** and pulling the handle **50** towards the body of the user while keeping the elbow in a generally stationary position. This is typically known as an exercise "curl." The elbow is preferably located such that the biceps are fully contracted and the line **40** is completely unwrapped from the axle 20. More preferably, a mark on the device or other structure, such as a padded member, is used to indicate the correct positioning of the elbow. When the inertia of the flywheel **10** and axle **20** causes the line **40** to begin wrapping around the axle **20**, the handle **50** is pulled towards the axle **20**. The

user preferably slows and gradually stops the rotation of the flywheel **10** and axle **20** by using the biceps. Thus, the biceps can be exercised in a positive and negative work portion during one exercise repetition.

In a preferred embodiment, the line **40** shown in **FIG. 1** is partially elastic. More preferably the portion of the line **40** which attaches to the axle **20** at the anchor **24** is partially elastic. Most preferably this portion of the line that is elastic is about 4 to 10 inches in length. Alternately, the portion of the line attached to the grip **50** may be elastic or the entire line **40** may be elastic or inelastic. The elastic line **40** allows a smoother transition between the unwinding of the line during the positive work portion of the exercise and the winding of the line during the negative work portion of the exercise. Otherwise, the line **40** may "snap-back" as the axle changes direction.

An encoder **90** or other similar device may be attached to the axle **20**. The encoder **90** can be used, for example, to provide an input to an instrumentation device (not shown) for determining information such rotational velocity, rotational acceleration, number of repetitions, and elapsed exercise time. The instrumentation device may include a display which may show the user, for example, the amount of force exerted and calories consumed during the exercise. For example, in the simple case where there is no spool and the line is always perpendicular to the axle, the relationship between rotational acceleration of the axle, α, and the torque, τ, applied to the axle is:

$$\tau = I \bullet \alpha, \qquad (1)$$

where I is the moment of inertia of the flywheel. Also, the relationship between force applied to the grip **50** and torque is:

$$F = \tau / r, \qquad (2)$$

where r is the radius of the axle. Combining equations (1) and (2) yields:

$$F = \alpha \bullet I / r. \qquad (3)$$

Thus, the force on the line can be computed from the rotational acceleration of the axle sensed by the encoder. The work exerted by the person performing the exercise is:

$$W = F \bullet x, \qquad (4)$$

where x is the linear distance over which the force, F, is applied, which can be expressed as:

$$x = 2\pi \cdot n \cdot r, \qquad (5)$$

where n is the number of axle rotations. Thus, the work expended by the exercise can be expressed as:

$$W = F \cdot 2\pi \cdot n \cdot r \qquad (6)$$

or

$$W = \alpha \cdot I \cdot 2\pi \cdot n, \qquad (7)$$

where F is determined from equation (3). Thus, the work expended can be computed from the number of axle rotations and rotational acceleration sensed by the encoder. This expended work may be expressed in units of calories and displayed to the person exercising. For different configurations of the inertial resistance exercise device, similar relations between rotational acceleration, force, number of rotations and calories burned can be expressed, calculated and displayed by an instrumentation device.

The force exerted by the user can be calculated. In this example, the flywheel **10** is a uniform density disk of radius, R. The flywheel's moment of inertia, I, can be expressed as:

$$I = \tfrac{1}{2} M \cdot R^2, \qquad (8)$$

where M is the flywheel mass. Rewriting equation (2) and substituting the above expression for I yields the following expression for the rotational acceleration of the flywheel:

$$\alpha = 2(F/M)(r/R^2). \qquad (9)$$

Further, the rotational displacement of the axle, in radians, can be expressed as:

$$\phi = \tfrac{1}{2}\alpha \cdot t^2. \qquad (10)$$

Thus, from equations (5), (9) and (10), the linear displacement of the grip may be expressed as:

$$x = (F/M)(r/R)^2 \cdot t^2 \qquad (11)$$

Using the above expression and assuming the following parameters for an inertia exercise device:

$F = 200$ newtons ($\approx$ 45 pounds)

$M = 10$ kilograms ($\approx$ 22 pounds)

$r = .02$ meter ($\approx 3/4$ inches)

$R = 0.2$ meter (≈ 8 inches)

$t = 2$ seconds;

yields: $x = .8$ meter ($\approx 2\frac{1}{2}$ feet).

Thus, an inertia exercise device utilizing a 10 Kg. (22 lb.) flywheel which has an .2 m. (8 in.) radius and is mounted to an axle having a .02 m. (3/4 in.) radius can accommodate an exercise having a .8 m (2½ ft.) range-of-movement over a 2 sec. interval under a constant 45 lb. force applied to the grip.

Referring again to **FIG. 1**, the inertial resistance exercise device according to the present invention may incorporate multiple pivot locations which can be used to adjust the difficulty of the exercise. The relationship between pivot location and exercise difficulty can be understood by considering the relationship between the force applied to the grip, F, and the resulting torque, τ, applied to the axle. The torque, τ, is equal to the component of force, F, which is exerted perpendicular to the axle, $F\perp$, times the "moment arm," ρ, of that force. That is:

$$\tau = F\perp \cdot \rho, \qquad (12)$$

where ρ is equal to the perpendicular distance from the axis of the axle to the point of application of the force component, $F\perp$, on the axle.

The pivot location determines the amount of grip force, F, which is translated to $F\perp$. Specifically, the pivot location determines θ, which is the angle between the line **40** and the axle **20**. In turn, θ determines both $F\perp$ and $F\|$, where $F\|$ is the component of F which is parallel to the axle. The relationship between these force components and θ is:

$$F\perp = F \cdot \sin\theta \qquad (13)$$

$$F\| = F \cdot \cos\theta \qquad (14)$$

$$F^2 = F\perp^2 + F\|^2. \qquad (15)$$

These force relationships are illustrated in **FIGS. 2-3**.

FIGS. 2-3 are schematic representations of the flywheel **10**, axle **20**, spool **30** and line **40**. Also depicted in **FIGS. 2** and **3** are vector force diagrams **90, 92** illustrating the grip force, F; its components perpendicular and parallel to the axle, $F\perp$ and $F\|$, respectively; and the angle θ between the line **40** and the axle **20**. A

comparison of **FIGS. 2** and **3** illustrates the effect of pivot location on exercise difficulty. The angle θ between the line **40** and the axle **20** varies as the distance and position of the pivot **60** is adjusted relative to the axle **20**. In **FIGS. 2A-C**, the pivot **60** is located a greater distance from the axle **20** than in **FIGS. 3A-C**. For example, in **FIG. 2B** θ is greater than for the similar line position shown in **FIG. 3B**. Similarly, in **FIG. 2C** θ is greater than for the similar line position shown in **FIG. 3C**. The impact of pivot location on exercise difficulty is apparent from a comparison of the vector diagrams **90A-C** and **92A-C** of **FIGS. 2-3**. The perpendicular component of line force, $F\perp$, contributes to axle torque, i.e., the force rotating the flywheel **10**. Therefore, because the component of line force perpendicular to the axle $F\perp$ is greater in **FIGS. 2B-C** than in **FIGS. 3B-C**, the pivot location shown in **FIG. 2** results in a relatively easier exercise to the user because less force must be exerted on the grip to create the same rotational force. In other words, moving the pivot **60** closer to the axle **20**, as in **FIGS. 3A-C**, decreases θ and reduces the torque for a given line force, making the exercise relatively harder. Similarly, moving the pivot farther from the axle, as in **FIG. 2A-C**, increases θ and increases torque for a given line force, making the exercise relatively easier. Further, θ affects the snap-back which may occur when the axle changes direction. The smaller the angle θ, the smoother the transition between the positive and negative portions of the exercise.

The pivot location also determines the moment arm, ρ, of $F\perp$ because the pivot location determines the position of the line on the spool. The spool **30** preferably has a radius that is a function of distance along the length of the spool **30**. More preferably, the spool **30** is conical in shape with a constantly increasing radius. Alternatively, it will be understood the spool **30** may comprise a variety of shapes and sizes depending upon the desired exercise resistance of the user. The moment arm, ρ, is equal to the spool radius at the point of contact between the line and the spool. This relationship between pivot location and ρ is illustrated in **FIGS. 3-4**.

In **FIG. 3A**, the pivot **60** is located proximate the wide end **34** of the spool **30**. In this position, the first line wrap **46** is coiled around this wide end **34** at the beginning and end of an exercise cycle. By comparison, in **FIG. 4A**, the pivot **60** is located proximate a middle portion **33** of the spool **30**, between the wide end **34** and

the narrow end **32**. It follows that the torque, τ, for a given line force, F, is greater in **FIG. 3A** than in **FIG. 4A** because the moment arm, ρ, at the wide end **34** of the spool **30** is greater than at a middle portion **33** of the spool **30**. Thus, it is easier to start and end the rotation of the axle **20** in **FIG. 3A** than in **FIG. 4A**. By comparing **FIG. 3B** with **FIG. 4B** and **FIG. 3C** with **FIG. 4C**, it is also clear that this mechanical advantage of a greater moment arm is present throughout the exercise cycle for the pivot location in **FIG. 3** as compared with **FIG. 4**. Hence, the exercise is relatively easier as the pivot **60** is located closer to the wide end **34** of the spool and relatively harder as the pivot is located closer to the narrow end **32** of the spool.

Referring again to **FIG. 1**, the spool **30** affects the force-speed exercise profile. That is, the spool shape determines the relationship between force applied to the grip **50** and the linear velocity of the grip **50**. With free-weights, an exercise can be performed with a constant applied force at any speed-of-movement. For example, free-weights allow a constant force and constant speed exercise profile. By comparison, without a spool, a constant pull force applied to the grip **50** would result in an acceleration of the axle and an increasing speed-of-movement.. To maintain a constant speed-of-movement, for instance, a decreasing applied force would be necessary throughout the positive movement portion of the exercise cycle.

For example, in the simple case where there is no spool and the line force, F, is always applied perpendicular to the axle, as shown in **FIG. 4D**, the relationship between the work applied by the user and the resulting kinetic energy created in the flywheel is:

$$F \cdot x = \tfrac{1}{2} I \cdot \omega^2, \qquad (16)$$

where x is the linear distance over which the force, F, is applied; I is the flywheel's moment of inertia; and ω is the angular velocity of the flywheel. The relationship between the linear velocity, v, of the exercise movement and the angular velocity of the flywheel is:

$$v = \omega \cdot r, \qquad (17)$$

where r is the radius of the axle around which the line **40** is wrapped, assuming a tightly wrapped coil. Thus:

$$F \cdot x = \tfrac{1}{2} \cdot I \cdot (v/r)^2 \qquad (18)$$

or $$(dx/dt)^2 - 2(F \cdot r^2/I) \cdot x = 0. \tag{19}$$

Solving (19) for x yields:

$$x = \tfrac{1}{2} \cdot (F \cdot r^2/I) \cdot t^2, \tag{20}$$

where t is the time duration of the exercise. It is therefore apparent from equation (20) that, without a spool, for a constant applied force, F, the speed-of-movement is proportional to the square of the duration that the force is applied. That is, there is not a constant force and constant speed exercise profile without a spool.

In a preferred configuration, a spool **30** with a generally conical shape is utilized to achieve a force and speed-of-movement exercise profile which provides a generally constant force and generally constant speed of movement exercise profile. Referring again to **FIG. 1**, at the beginning of an exercise cycle, with the line **40** in its wrapped position **44**, the line **40** extends away from the axle near the wide end **34** of the conical spool **30**. Thus, a relatively small force on the grip **50** is required to accelerate the axle **20**, and a relatively large amount of line **40** unwraps from the spool **30** per revolution of the axle **20**. This compensates for the relatively small initial rotational velocity of the axle **20**. By the time the line **40** is near its unwrapped position **42**, the line extends away from the axle **20** near the narrow end **32** of the conical spool **30**. In this position, a relatively large amount of force on the grip **50** is required to accelerate the axle **20**, and a relatively small amount of line **40** is being unwrapped from the axle **20** per revolution. This, however, compensates for the relatively large rotational velocity of the axle **20** at this portion of the exercise cycle. The spool also has the effect of allowing the line to unwrap to a small diameter, reducing the snap-back when the axle reverses directions. One of ordinary skill in the art will recognize that other spool shapes will result in a variety of force-speed exercise profiles.

The spool **30** illustrated in **FIG. 1** may be a variety of shapes and may extend the entire length of the axle or only a portion of the axle. In a preferred embodiment shown in **FIG 1**, the spool **30** is conical in shape, with a narrow end **32** near the anchor **24** and a wide end **34** which is farther from the anchor **24**. Preferably the anchor **24** is configured immediately adjacent the spool narrow end **32** such that the line **40** can wrap almost the entire length of the spool **30**.

FIG. 5 illustrates another embodiment of a flywheel assembly for an inertial resistance exercise device according to the present invention. As in the embodiment illustrated in **FIG. 1**, this embodiment has a spool **30** mounted on a first axle **20** which is supported by bearings **22**. Also, as in **FIG. 1**, this embodiment has a line **40** which is attached to the axle **20** at one end by an anchor **24**. Unlike the embodiment of **FIG. 1**, however, the embodiment illustrated in **FIG. 5** has a flywheel **10** mounted on a second axle **520** which is supported by a second set of bearings **522**. The two axles **20, 520** are interconnected with a synchronizing assembly **580** such that rotation of one axle causes the other axle to rotate.

In one embodiment of the synchronizing assembly **580**, a first sprocket **530** is mounted on the first axle **20**. A second sprocket **540** is mounted on the second axle **520**. The first sprocket **530** and second sprocket **540** are interconnected by a substantially inelastic line **550**. If the first sprocket **530** has a larger diameter than the second sprocket **540**, this configuration causes the second axle **520** to rotate faster than the first axle **20**. Thus, for the same flywheel **10** mass (as shown in **FIG. 1**), a higher force is required for the configuration of **FIG. 5** than the configuration of **FIG. 1**. For example, if the first sprocket **530** is four times larger in diameter than the second sprocket **540**, a given pull force on the line **40** causes the second axle **520** to rotate four times faster than the first axle **20**. Thus, the work required for a given rate of pull is sixteen times higher than if the flywheel **10** were mounted on the first axle **20**. Alternatively, the first sprocket **530** may have a smaller or equal diameter to the second sprocket **540**.

It will be understood that multiple sprockets of various diameters may be mounted on each axle such that various relative axle speeds may be achieved merely by relocating the line **550**. One skilled in the art will understand the line **550** may comprise a chain, cog belt, or pulley belt or the like to interconnect the appropriate pair of sprockets. The two axles shown in **FIG. 5** may also be interconnected with a line which wraps onto one axle as it wraps off the other axle. This axle connecting line could be used as the synchronization assembly or in conjunction with a separate synchronization assembly.

FIG. 6 illustrates yet another embodiment of a flywheel assembly for an inertial resistance exercise device according to the present invention. As in the embodiment illustrated in **FIGS. 1** and **5**, this embodiment has a spool **30** mounted on a first axle **20** which is supported by bearings **22**. Also as in **FIGS. 1** and **5**, this embodiment has a line **40** which is attached to the axle **20** at one end by an anchor **24**. Unlike these other embodiments, however, the embodiment illustrated in **FIG. 6** has a flywheel **10** in the form of spring-loaded weights. That is, the flywheel **10** has weights **12** attached to the axle **520** or another portion of the flywheel with one or more springs **14**. These spring-loaded weights **12** move away from the axle **520** with faster rotational velocities of the axle **520**. For example, in an initial position (shown in phantom), the weights **12** are positioned generally proximate to the axle **520**. As the axle **520** rotates, the weights **12** move away from the axle **520** as shown. As the weights **12** move away from the axle **520**, this increases the moment of inertia of the flywheel **10**, increasing the force which must be applied to the grip **50** to continue to accelerate the flywheel **10** as its rotational velocity increases. Thus, a spring-loaded flywheel **10** creates a governor-like flywheel mechanism and can be used to modify the force-speed exercise profile.

FIG. 6 also illustrates an alternative embodiment of the spool **30** in which the spool **30** is constructed to have a variable-slope surface. Varying the spool slope alters the force-speed exercise profile as discussed above. To allow varying of the spool slope, the spool **30** may be composed of rods or sections **34** having swivel points **35**, **36** at the spool ends and the rods **34** are connected at hinge points **37**. Preferably, the swivel points **36** at one end of the spool **30** are connected to a slidable sleeve **38** mounted to the axle **20**. The sleeve **38** can be moved along the axle **20** in one direction to cause the rods or sections **34** to swivel away from the axle **20**, increasing the spool slope and in the opposite direction to cause the rods or sections **34** to swivel toward the axle **20**, decreasing the spool slope.

It will be understood that the rods or sections **34** and sleeve **38** may be used in conjunction with weights **12** to vary the distance of the weights **12** from the axle **520**. Such an arrangement may be used with or without springs to modify the inertia of the flywheel **10**.

FIG. 7 illustrates yet another embodiment of the inertial resistance exercise device according to the present invention. As in the embodiments illustrated in **FIGS. 1** and **5**, this embodiment has a flywheel **10** mounted on an axle **20** supported by bearings **22**. In the embodiment of **FIG. 7**, both ends of the line **40** are attached to the axle **20**. In one embodiment, the ends of the line **40** are attached proximate the center **726** of the axle **20**. A wrapped portion **741** of the line **40** is formed by coiling the line **40** about the axle **20** on either side of the axle center **726**. As another alternative, the ends of the line **40** may be attached at separate points on either side of the axle center **726**, with the wrapped portion **741** being formed by coiling the line **40** about the axle **20** and toward the axle center **726**. As yet another alternative, the ends of the line **40** are attached together to form a continuous loop, which is also wrapped about the axle **20**. A center portion **743** of the line **40** extends away from the axle **20** and is supported by a single pivot **760**. Alternatively, the center portion **743** may be supported by a plurality of pivots **760** similarly located (as shown, for example, in phantom).

The inertial resistance exercise devices illustrated in **FIGS. 1, 5** and **6** involve the same muscle group performing both positive and negative work. The positive work portion of the exercise oscillates with the negative work portion of the exercise each time the rotation of the axle changes direction. In contrast, the inertial resistance exercise device illustrated in **FIG. 7** provides an exercise in which one muscle group performs a positive work portion and an antagonist muscle group performs a negative work portion for each direction of axle rotation. The positive and negative movements of the exercise oscillate between muscle groups each time the rotation of the axle changes directions.

Referring to **FIG. 7**, a grip **752** may be attached to one side **745** of the line center portion **743**. Another grip **754** may be attached to the side **747** of the line center portion **743** on the opposite side of the pivot or pivots **760**. A force applied to one grip or both grips **752**, **754** in opposite directions causes the axle to rotate in one direction. As the axle rotates, the total amount of line **40** coiled about the axle generally does not increase or decrease because the line **40** wrapped around one side

of the axle is unwrapped at the same speed as the line **40** is wrapped around the other side of the axle.

When the user applies force to one or both grips **752, 754**, the rotational velocity of the flywheel **10** increases and the user performs positive work. At any point, the user can cease applying force to the grips **752, 754** in one direction and apply a force to the one or both grips **752, 754** in the another direction. This causes the rotational velocity of the flywheel **10** to decrease, allowing the user to perform negative work. This negative work portion of the exercise continues until the flywheel **10** stops and the axle **20** begins to rotate in the opposite direction, once again starting a positive work portion. Thus, a full cycle or repetition of this exercise involves, for example, positive work applied to the first grip **752**; negative work applied to the opposite grip **754**; positive work applied to the opposite grip **754**; and, finally, negative work applied to the first grip **752**. A similar exercise repetition could be described involving force applied to both grips **752, 754** in opposite directions.

Referring to **FIG. 7**, many variations of this embodiment are possible. No pivots need be used, but one or more pivots may be used. The variations of the flywheel described with respect to the other aspects of the invention may be incorporated into the flywheel **10** mounted on the axle **20**. The flywheel **10** can also be mounted to the axle **20** with a one-way clutch. In that manner, the flywheel inertia is only applied to the axle when the axle **20** rotates in one direction. Similarly, multiple flywheels **10** may be mounted to the axle **20**, either with no clutch or with one-way clutches which engage in one of either rotational direction.

It will be understood that the present invention can be utilized in many different configurations. For example, in an embodiment not shown in the accompanying figures, a first flywheel having a primary mass can be directly mounted to the axle along with a second flywheel having a smaller secondary mass mounted with a one-way clutch. With that configuration, the primary mass acts on the axle in either rotational direction, but the secondary mass only acts on the axle in one rotational direction. Thus, the exercise difficulty can be made to vary depending on the particular phase of the exercise cycle. Further, one or two spools of the type described herein with respect to other aspects of the invention may be incorporated

into the embodiment shown in **FIG. 7** so that the coiled portion **741** of the line on either side of the axle center **726** wraps onto a spool, varying the force-speed exercise profile as described above.

FIG. 8 illustrates an inertial resistance exercise device **800** according to the present invention, utilizing the flywheel mechanism described above with respect to **FIG. 1**. A frame **802** containing bearings **22** is mounted to a base **806**. The axle **20** is located vertically within the frame **802** and mounted to the bearings **22**. Of course, the axle **20** could be located in a horizontal position or any other desired orientation. Mounted on the axle **20** is a flywheel **10** and a spool **30**. Multiple primary pivots **862-866** are located at multiple locations along a vertical member **804** of the frame **802**. Alternatively, a single fixed or movable pivot may also be utilized. A post **808** is mounted in proximity to the frame **802**. The post **808** supports multiple secondary pivots **867, 869** or a single fixed or movable secondary pivot (not shown). One end of a line **40** is attached to the axle **20** at an anchor **24**. The other end of the line **40** is attached to a grip **50**. The line **40** is preferably supported by one of the primary pivots **862-866** and one of the secondary pivots **867, 869**. For the embodiment shown in Fig. 8, the most difficult exercise for the user occurs when the upper primary pivot **862** is used. For the easiest exercise, the lower primary pivot **866** is used. For moderate exercise, the central primary pivot **864** is used.

Depending on the secondary pivot used, a variety of exercises can be performed. If the upper secondary pivot **867** is used, the grip **50** can be held so that the line **40** is in a generally horizontal position **848** and pulled in a generally horizontal direction. For example, with the inertial resistance exercise device configured in this manner, an individual standing sideways to this exercise device could pull the grip **50** in a cross-chest movement to exercise the posterior deltoid. If, with the same configuration, the grip **50** is held so that the line **40** is in a generally vertical position **846**, an individual standing facing the exercise device can pull the grip **50** downward to exercise the triceps.

If the lower secondary pivot **869** is used, the grip **50** can be held so that the line **40** is in a generally horizontal position **842** and pulled in a generally horizontal direction. For example, with the inertial resistance exercise device configured in this

manner, an individual seated facing the exercise device can perform a seated row exercise to exercise the latissimus dorsi by pulling the grip **50** towards their body. In the same configuration, the grip **50** can be held so that the line **40** is in a generally vertical position **844** and pulled in a generally vertical direction. For example, a individual seated facing the exercise machine can perform an upright row to exercise the trapezius by pulling the grip **50** upwards next to their body.

One of ordinary skill will appreciate many variations of the inertial resistance exercise device illustrated in **FIG. 8**. The dual-axle flywheel mechanism illustrated in **FIG. 5** can be utilized in place of the single-axle flywheel mechanism illustrated in **FIG. 1**. Further, any of the variations of those mechanisms described above can be incorporated in the exercise machine of **FIG. 8**. Many other variations are also possible. Additionally, the grip **50** can take many different forms, such as a single handle, two connected handles, various shaped bars for gripping by one or two hands, and various straps or ropes, to name a few.

The line **40** may also be attached to a floor-mounted grip device **850** to create an additional variety of exercise options. For example, a bar **852** may be hinged at one end and have a grip **856** at the opposite end. The line **40** is attached to the bar at point **858**. In this manner, pulling the bar **852** creates a pulling force on the line. This basic mechanism can be modified so that a variety of grip positions are available. Further, the bar **852** can be replaced with two bars configured for a rowing movement.

In a preferred embodiment, the flywheel **10** illustrated in **FIG. 8** is a disk shaped to have greater mass on or near its outer diameter. Most preferably, a diameter of the flywheel has a generally "dog-bone" shaped cross-section. The preferred flywheel has a radius in the range of 2 to 15 inches and a weight in the range of 2 to 30 pounds. In a more preferred embodiment, the flywheel **10** of **FIG. 8** has a radius in the range of 6 to 8 inches and a weight in the range of 10 to 12 pounds.

In a preferred embodiment, the spool **30** illustrated in **FIG. 8** has a base radius in the range of 1/2 to 1-1/2 inches and a length in the range of 4 to 24 inches. In a more preferred embodiment, the spool **30** of **FIG. 8** has a base radius in the range of 3/4 to 1 inches and a length in the range of 8 to 12 inches.

FIG. 9 illustrates an inertia exercise device **900** according to the present invention, utilizing the flywheel mechanisms and variations described above with respect to other aspects of the invention to create a variety of inertia exercises. The exercise device **900** includes a frame **902** and legs **904** which support the exercise machine **900** on a generally flat surface such as a floor. The frame **902** includes two sets of bearings **22, 522**. A first axle **20** is preferably rotatably mounted within bearings **22**. A second axle **520** is preferably rotatably mounted within bearings **522**. A flywheel **10** is mounted onto the second axle **520** and a linkage **952** is connected to the first axle **20**. The linkage **952** is preferably a rigid bar with one end fixed to the axle **20** and a grip **950** attached to the other end. The rigid bar, in contrast to a line, allows the user to apply both a pulling and pushing force to the axle **20**. Alternatively, a one way clutch may be used to connect the member **952** to the axle **20** so that the user can apply force to the axle **20** in only one direction. A synchronizing assembly **580** having a first sprocket **530** mounted on the first axle **20** and a second sprocket **540** mounted on the second axle **520** connects the two axles via a substantially inelastic line such as a chain **550**.

In operation, a user exercises by applying an alternating pushing and pulling force to the handle **950**. This creates an exercise having positive work and negative work portions involving antagonistic muscle groups for each direction of axle rotation, similar to that described with respect to the flywheel mechanism of **FIG. 7**. That is, a pulling force applied to the grip **950** causes the axle **20** to rotate in one direction. Hence, the synchronizing assembly **580** causes the second axle **520** to rotate. During this phase of the exercise, the rotational velocity of the flywheel **10** increases, resisting the pulling force. One muscle or muscle group of the user, e.g., biceps, contracts under this load, performing positive work. At any point, the user can cease applying a pulling force to the grip **950** and instead apply a pushing force to the grip **950**, resisting the rotation of the first axle **20**. The rotation of the second axle **520** also slows, due to the synchronizing assembly **580**. This causes the flywheel **10** to decrease its rotational velocity, resisting the pushing force. During this phase of the exercise, a different muscle or muscle group, e.g., triceps, are elongating under load, performing negative work. This negative work portion of the exercise continues until

the flywheel **10** stops and the axle **20** begins to rotate in the opposite direction, once again starting a positive work portion.

A full cycle or repetition of an exercise utilizing the inertia device of **FIG. 9**, thus, involves a positive work pulling force of a muscle group applied to the grip **950**; a negative work pushing force of an antagonist muscle group applied to the grip **950**; a positive work pushing force of a muscle group applied to the grip **950**; and, finally, a negative work pulling force of the antagonist muscle group applied to the grip **950**. The synchronizing assembly **580** advantageously incorporates multiple sprockets of various sizes mounted on each axle such that various relative axle speeds may be achieved as described above with respect to **FIG. 5**. This allows the difficulty of the described exercise to be easily varied to suit different users or varying strength of a single user. One of ordinary skill in the art will recognize that the flywheel, grip and synchronizing assembly variations described in connection with **FIGS. 1-8** above can be incorporated into the inertia exercise device of **FIG. 9**.

One of ordinary skill will also recognize many variations with respect to the arrangement of **FIG. 9**. For example, the linkage **952** may be connected to either sprockets **530, 540** or fly wheel **10** so that torque is applied directly to the sprockets **530, 540** or fly wheel **10**, and not the axle **20**. Moreover, the linkage may comprise a flexible rod, partially elastic connector, curved member, etc., depending upon the desired exercise to be performed.

In a preferred embodiment, the flywheel **10** illustrated in **FIG. 9** is a disk shaped to have greater mass on or near its outer diameter. Most preferably, a diameter of the flywheel has a generally "dog-bone" shaped cross-section. The preferred flywheel has a radius in the range of 2 to 15 inches and a weight in the range of 2 to 30 pounds. In a most preferred embodiment, the flywheel **10** of **FIG. 9** has a radius in the range of 6 to 8 inches and a weight in the range of 10 to 12 pounds.

In a preferred embodiment, the synchronizing assembly **580** illustrated in **FIG. 9** consists of sprockets having diameters in the range of 2 to 10 inches and having diameter ratios between the two axles ranging from 2 to 10.

FIG. 10 illustrates an example of an inertia exercise device **1000** utilizing a flywheel mechanism similar to that of **FIG. 7**. The exercise device **1000** includes a

frame **1002** and legs **1004** which support the exercise machine **1000** on a generally flat surface such as a floor. The frame **1002** includes bearings **22** within which an axle **20** is preferably rotatably mounted. A flywheel **10** is mounted onto the axle **20** and a line **40** is wrapped around the axle **20** creating a coiled portion **1040** and left and right end portions extending away from the axle. The left and right end portions of the line **40** are disposed between left and right pinch rollers **1006** and **1008** to maintain tension in the line. Left and right grips **1052** and **1054** are attached at the ends of the left and right end portions, respectively.

In operation, a user exercises by applying alternating pulling forces to the left and right grips **1052, 1054**. This creates an exercise having oscillating positive work and negative work portions on opposite limbs. That is, a pulling force applied, for example, to the left grip **1052** causes the axle **20** to rotate in one direction. During this phase of the exercise, the rotational velocity of the flywheel **10** increases, resisting the pulling force. The muscles in the user's left arm contract under this load, performing positive work. At any point, the user can cease applying a pulling force to the left grip **1052** and instead apply a pulling force to the right grip **1054**, resisting the rotation of the axle **20**. This causes the flywheel **10** to decrease its rotational velocity, resisting the pulling force on the right grip **1054**. During this phase of the exercise, the muscles in the right arm are elongating under load, performing negative work. This negative work portion of the exercise continues until the flywheel **10** stops and the axle **20** begins to rotate in the opposite direction, once again starting a positive work portion. A full cycle or repetition of an exercise utilizing the inertia device of **FIG. 10**, thus, involves a positive work pulling force applied to a first grip; a negative work pulling force applied to a second grip; a positive work pulling force applied to the second grip; and, finally, a negative work pulling force applied to the first grip. One of ordinary skill in the art will recognize that the flywheel and grip variations described in connection with **FIGS. 1-9** above can be incorporated into the inertia exercise device of **FIG. 10**. One of ordinary skill will also recognize many variations with respect to the frame and arrangement of **FIG. 10**.

In a preferred embodiment, the flywheel **10** illustrated in **FIG. 10** is a disk shaped to have greater mass on or near its outer diameter. Most preferably, a diameter

of the flywheel has a generally "dog-bone" shaped cross-section. The preferred flywheel has a radius in the range of 2 to 15 inches and a weight in the range of 2 to 30 pounds. In a most preferred embodiment, the flywheel **10** of **FIG. 10** has a radius in the range of 6 to 8 inches and a weight in the range of 10 to 12 pounds.

As seen in **FIG. 11**, a flywheel mechanism similar to that shown in **FIG. 9** may be incorporated into an inertia exercise device **1100** (shown in phantom) to provide a climbing exercise. The climbing exercise machine **1100** includes a base **1102** that supports the exercise machine **1100** on a generally flat surface such as a floor. The base **1102** includes three outwardly extending arms **1104** which are located in generally the same plane to provide a tripod support for the exercise machine **1100**. Generally vertically extending from the base **1102** and proximate the interconnection of the arms **1104**, is a frame **1106**. Located within the frame **1106**, proximate the base **1102**, is a first sprocket **1160**. Located proximate the other end of the frame **1106** is a second sprocket **1162**. These sprockets **1160** and **1162** are interconnected by a chain **1164**, cog belt or other similar substantially inelastic connection.

The frame **1106** includes longitudinally extending openings or slots **1108** formed on opposing sides of the frame **1106**. Extending through the slots **1108** are left and right pedals **1152** and **1154**, and left and right handles **1156** and **1158**, respectively, which are attached to the chain **1164**. The pedals **1152** and **1154** are located proximate the base **1102** of the exercise machine **1100**, and the handles **1156** and **1158** are located proximate the other end of the frame **1106**. One skilled in the art, of course, will understand the climbing exercise machine may be used with any of the embodiments of the invention.

The climbing exercise machine may be similar to that disclosed in U.S. Patent No. 5,040,785 which issued August 20, 1991, entitled "Climbing Exercise Machine", and invented by the same inventor as the present invention. The disclosure of U.S. Patent No. 5,040,785 is hereby incorporated by reference. The climbing exercise machine may also be similar to that disclosed in U.S. Patent No. 5,492,515 which issued February 20, 1996, entitled "Climbing Exercise Machine" and invented by the same inventor as the present invention. The disclosure of U.S. Patent No. 5,492,515 is hereby incorporated by reference. Additionally, the climbing exercise machine may

be similar to that disclosed in pending Application No. 08/576,130 which was filed on December 21, 1995, entitled "Climbing Exercise Machine" and invented by the same inventor as the present invention. The disclosure of pending Application No. 08/576,130 is hereby incorporated by reference.

As shown in **FIG. 11**, the sprocket **1162** is preferably connected to a rotatable axle **20**. The axle **20** preferably rotates within bearings **22**. A second axle **520** is preferably located parallel to the first axle **20**. This second axle **520** is preferably rotatably mounted within bearings **522**. A flywheel **10** is mounted on the second axle **520**. The first axle **20** and the second axle **520** are connected by a synchronizing assembly **580**. The synchronizing assembly has one or more sprockets **530** mounted on the first axle **20** and one or more sprockets **540** mounted on the second axle. The sprockets **530** and **540** are engaged with a chain **550**, cog belt or other substantially inelastic connection. One of ordinary skill in the art will understand that the number of sprockets and diameters of the sprockets may depend upon the desired range of exercise difficulty.

As an alternative embodiment, the synchronization assembly may include a variable gear ratio transmission (not shown). The transmission allows the axles **20** and **520** to be interconnected to provide a different and adjustable range of motion between the axles. The transmission may be any of a large number of well known variable transmissions. The transmission eliminates the need for the chain **550** to interconnect the sprockets **530** and **540**, and it maintains the synchronized movement of the handles and pedals.

In a preferred embodiment, the flywheel **10** illustrated in **FIG. 11** is a disk shaped to have greater mass on or near its outer diameter. Most preferably, a diameter of the flywheel has a generally "dog-bone" shaped cross-section. The preferred flywheel has a radius in the range of 2 to 12 inches and a weight in the range of 4 to 15 pounds. In a most preferred embodiment, the flywheel **10** of **FIG. 11** has a radius in the range of 4 to 5 inches and a weight in the range of 6 to 12 pounds.

In a preferred embodiment, the synchronizing assembly **580** illustrated in **FIG. 11** consists of sprockets having diameters in the range of 2 to 10 inches and having diameter ratios between the two axles ranging from 2 to 10.

FIG. 12 illustrates an alternative embodiment of the climbing exercise machine incorporating a flywheel mechanism similar to that shown in **FIG. 7**. In this embodiment the center portion **743** of a line **40** is supported by sprockets **760**. A coiled portion **741** of the line **40** is wrapped around an axle **20**. The axle **20** is supported by bearings **22**, and mounted on the axle **20** is a flywheel **10**. Extending through slots **1108** in the frame **1106** are left and right pedals **1152** and **1154** and left and right handles **1156** and **1158**, respectively, which are attached to the line **40**. The pedals **1152** and **1154** are located proximate the base **1102** of the exercise machine **1100**, and the handles **1156** and **1158** are located proximate the other end of the frame **1106**.

In operation of either embodiment of the climbing machine, as illustrated in **FIGS. 11-12**, the movement of the foot pedals **1152** and **1154**, and the hand pedals **1156** and **1158** allow the user to exercise. In one preferred embodiment of the invention, the handles and pedals preferably move in coordinated and synchronized movement such that when the handle and pedal on one side of the machine move in one direction, the handle and pedal on the opposite side of the machine move in the opposite direction. Thus, while the handle and pedal are moving upwardly on one side of the machine, the handle and pedal are moving downwardly on the other side of the machine. Additionally, both handles **1156** and **1158** are moving at the same velocity because they are interconnected by the chain **1164** shown in **FIG. 11** or the line **40** shown in **FIG. 12**. Likewise, both pedals **1152** and **1154** are moving at the same velocity.

Referring to **FIG. 11**, the upward and downward movement of the handles **1156** and **1158** and pedals **1152** and **1154** causes periodic movement of the chain **1164** and periodic rotation of the sprocket **1162**. The rotation of the sprocket **1162** causes the axle **20** and sprocket **530** to rotate. The rotation of the sprocket **530** causes the chain **550** and sprocket **540** to rotate. This rotation accelerates the flywheel **10** whose inertia causes an exercise producing resistance to the movement of the handles and pedals. Referring to **FIG. 12**, the upward and downward movement of the handles **1156** and **1158** and pedals **1152** and **1154** causes periodic movement of the line **40** and periodic rotation of the axle **20**. This rotation accelerates the flywheel **10**

whose inertia causes an exercise producing resistance to the movement of the handles and pedals.

One of ordinary skill in the art will understand that a wide variety of climbing machines may be utilized with the present invention. For example, climbing machines with a cross crawl or homolateral movement may also be utilized. By eliminating the handles and shortening the frame of the exercise device of **FIG. 12**, it becomes a stepper exercise machine. By adding a seat and inclining the frame of the exercise device of **FIG. 12**, it becomes an inclined or recumbent linear exercise machine. The climbing machines previously disclosed and incorporated by reference in connection with **FIG. 11** may also be utilized in connection with the exercise device of **FIG. 12**.

In a preferred embodiment, the flywheel **10** illustrated in **FIG. 12** is a disk shaped to have greater mass on or near its outer diameter. Most preferably, a diameter of the flywheel has a generally "dog-bone" shaped cross-section. The preferred flywheel has a radius in the range of 2 to 12 inches and a weight in the range of 5 to 25 pounds. In a most preferred embodiment, the flywheel **10** of **FIG. 12** has a radius in the range of 6 to 8 inches and a weight in the range of 12 to 15 pounds.

The inertial exercise apparatus and method according to the present invention has been disclosed in detail in connection with the preferred embodiments, but these embodiments are disclosed by way of examples only and are not to limit the scope of the present invention, which is defined by the claims that follow. One of ordinary skill in the art will appreciate many variations and modifications within the scope of this invention.